

ENAMELS

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UNDERCOAT ENAMELS USING METALLURGICAL SLAG

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A composition of undercoat enamel for steel is developed, whose main material component is blast-furnace slag from Novolipetsk Steel and Iron Works. The main properties of the obtained enamel are determined, and the optimum conditions for the synthesis of a high-quality undercoat sheet-steel enamel are described.

Currently, enameling production involves the traditional two-stage enameling technology. This technology implies preliminary application of an undercoat and its firing at a temperature of 850–950°C.

The main purpose of undercoat enamel is to level the thermal coefficient of linear expansion (TCLE) of metal and surface enamel and to develop strong adhesion between the two layers. Undercoat enamel batches include substantial quantities of costly and scarce raw materials.

Because of the need to save energy and material resources, it is expedient to use industrial waste for preparation of undercoat enamel frits for steel.

Metallurgy generates huge quantities of waste. Blast-furnace slag, in contrast to other types of metallurgical slag, has the most stable chemical composition, including SiO_2 , CaO , MgO , and Al_2O_3 , as well as manganese and ferric oxides. Consequently, grounds exist for using this slag as a complex material for preparation of undercoat enamel frits for steel coating.

Research in using different slags in the production of undercoat enamels for steel articles was carried out earlier (USSR Inventor's Certif. 1590990 and 585131) [1, 2]. However, there are no data on the use of blast-furnace slag of the Novolipetsk Iron and Steel Works (NISW) as a material for enamel production, and yet the Lipetsk Pipe Plant company, which produces enameled steel products (bathtubs, sinks, washstands, consumer goods), is interested in investigating the possibility of using the NISW slag.

The purpose of the present study was to investigate the possibility of replacing some undercoat enamel components with NISW blast-furnace slag and developing batch formulas with the optimum slag content to produce undercoat enamels

for steel that would meet the requirement of GOST 24405–80.

The blast-furnace slag has the following chemical composition (wt.%): 41.55 SiO_2 , 40.96 CaO , 9.16 MgO , 6.87 Al_2O_3 , 0.78 FeO , 0.53 MnO_2 , and 0.65 S. This slag differs from the slags used earlier in its low content of sulfide sulfur, high content of SiO_2 , and the absence of toxic phosphoric oxide.

Based on the published data, 200 undercoat enamel compositions were analyzed, and the most technologically suitable compositions, free of toxic components and having a high calcium oxide content, were selected (Table 1).

The components for batch preparation were blast-furnace slag from the Novolipetsk Steel and Iron Works, quartz sand from the Ramenskii deposit, soda ash, alumina, potash, boric acid, hematite, titanium dioxide, and nickel oxide (II). The last two ingredients were introduced into the batch above 100%. The amount of slag added to the batch was calculated based on the content of CaO in each composition of undercoat enamel (Table 2), for the purpose of introducing the maximum possible amount of slag to the undercoat composition.

Evaluation of the enamel properties was carried out according to the Appen method. The technical properties of coats were determined experimentally: the edge wetting angle was determined by the "sitting drop" method, the surface tension was determined by the "suspended drop" method, and the TCLE was determined by the dilatometric method. [5]. The main properties of the synthesized undercoat enamels are shown in Table 3.

Compositions 2 and 3 were eliminated from further investigation because of their high melting level and high surface tension.

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TABLE 1

Mixture	Weight content, %											Reference
	SiO ₂	Al ₂ O ₃	B ₂ O ₃	Na ₂ O	TiO ₂	MnO ₂	CaO	NiO	MgO	CoO	Fe ₂ O ₃	
1	59.3	2.3	—	22.5	—	—	13.2	—	—	0.3	2.4	[3]
2	55.4	6.4	22.6	—	—	0.3	14.8	0.2	—	0.3	—	[3]
3	49.0	3.3	8.9	24.5	—	1.0	10.0	3.1	—	0.2	—	[4]
4	42.4	7.0	14.4	21.6	1.0	—	12.6	0.6	—	0.4	—	[4]
5	46.4	2.03	7.2	22.4	—	—	16.0	2.4	1.43	—	2.14	USSR Inventor's Certif 1715726

TABLE 2

Mixture	Content, parts per 100 parts of enamel									
	slag	sand	soda	Al ₂ O ₃	H ₃ BO ₃	potash	TiO ₂	MnO ₂	NiO	Fe ₂ O ₃
1	32.00	46.21	38.97	—	—	—	—	—	—	2.54
2	36.00	40.62	19.56	35.43	—	17.17	—	—	0.20	—
3	24.00	39.19	42.44	1.05	14.04	—	—	1.00	3.10	—
4	31.00	29.12	37.42	4.17	22.71	—	1.03	—	0.60	—
5	39.00	30.33	38.82	—	11.33	—	—	—	2.40	2.27

TABLE 3

Mixture	Estimated properties				Experimental properties	
	density, kg/m ³	elasticity modulus, 10 ⁻³ kg/mm	surface tension, N/m	fusibility factor, °C	temp. of initial melting, °C	TCLE, 10 ⁻⁷ °C ⁻¹
1	2660	7100	0.323	1012	750	135
2	2600	7220	0.321	1135	—	—
3	2760	7740	0.398	1031	—	—
4	2730	8790	0.301	993	750	131
5	2850	8000	0.316	765	700	139

Frits were melted at temperatures of 1250–1300°C for 1 h with subsequent granulation in water. The glass-melting process for undercoat enamel based on blast-furnace slag does not differ from the glass-melting process for undercoat enamels made of raw materials. However, melting of the batch using slag produces more intense gas emission, due to the presence of sulfide sulfur in the slag composition and its oxidation in melting.

In order to determine the optimum firing temperature for undercoat enamel, the following enamel slip composition was prepared: 100% frit, 2–5% bentonite clay, and 60–70 ml of water. The slip was deposited on preliminarily treated steel samples (grade 0.8-Yu) by the flow enameling method. After drying, the coating was fired in a laboratory muffle furnace within the temperature range 750–950°C with a rise step of 50°C and holding for 3 min.

Analysis of the results obtained revealed that the optimum is composition 5 with 39 parts of slag. As it was fired at 850°C, a well-fired dark-gray undercoat with metallic luster was formed without the visible surface defects typical of undercoat enamels. The less intense dark coloring of the undercoat compared with enamels based on batches without slag is

favorable for the deposition of light-colored surface-coat enamels.

This study in principle proved the possibility of using NISW slag as the main material for the synthesis of undercoat sheet-steel enamels, which in their properties are not inferior to the enamels made of traditional materials.

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